PALEONTOLOGICAL EVIDENCES OF THE ANTIQUITY OF DISEASE

By Professor ROY L. MOODIE

DEPARTMENT OF ANATOMY, COLLEGE OF MEDICINE, UNIVERSITY OF ILLINOIS, CHICAGO

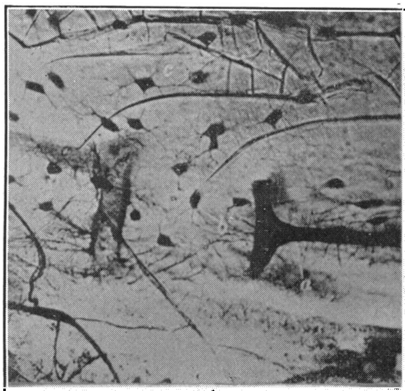
PATHOLOGICAL conditions among fossil animals are known as far back in geological time as the Carboniferous, hence it may be proper to state on the basis of our present knowledge that disease began, among both plants and animals, during the great Coal Period. These evidences are found both in the new and the old world, so that there must have been a very fundamental condition underlying the evolution and development of animal and plant races which favored the ingress of disease and the overpowering of the natural immunity which had previously protected the forms of life from the devastations of disease. This statement of affairs implies the absence of disease, or of a tendency toward disease, among the inhabitants of the earth during the geological periods prior to the Mississippian. This may not be correct, but so far as we know at present the animals of the Paleozoic and Proterozoic were free from disease. The factors which have been important in the origin of disease have been discussed by the writer[1] in an essay which had in view an outline of the entire subject of the origin and development of disease as seen in the lesions on fossil bones. A study of senescence in dogs and the relation of old age to disease recently made by Goodpasture[2] supports in an interesting manner a suggestion made by the writer[1] concerning certain factors in the origin of disease among the animals of past ages.

CARBONIFEROUS

Present evidences tend to show that the Coal Measures witnessed the origin of disease. The oldest known evidences of pathological conditions among fossil animals are to be found in the enlarged stems of fossil crinoids, which have been known for many years. They were described by Robert Etheridge, thirty-eight years ago, from the Carboniferous of Scotland. Five years later a correct interpretation of these deformities was given by L. von Graff. He showed, on the basis of similar

[1] " Studies in Paleopathology. I., General Consideration of the Pathological Conditions found among Fossil Animals," Annals of Medical History, Vol. 1, No. 4, 1918.

[2] " An Anatomical Study of Senescence in Dogs, with especial Reference to the Relation of Cellular Changes of Age to Tumors," *Journ. Med. Research*, Vol. XXXVIII., No. 2, pp. 127–190, 1918.



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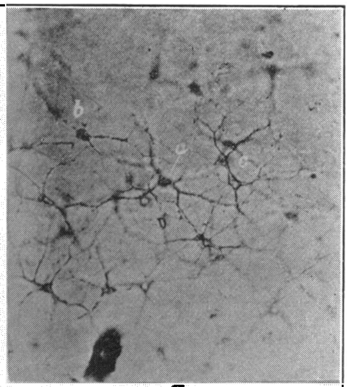

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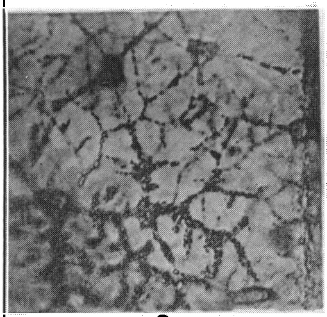

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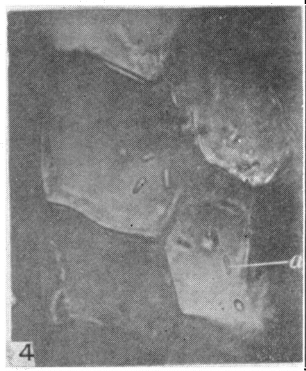

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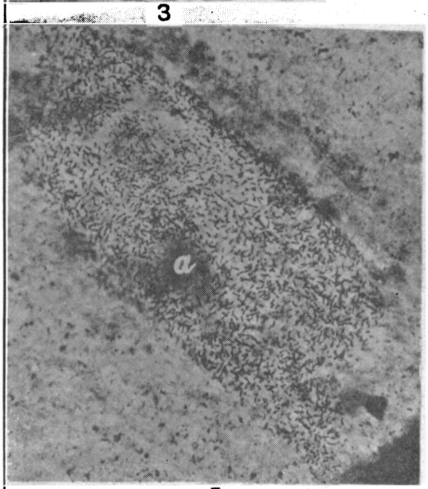

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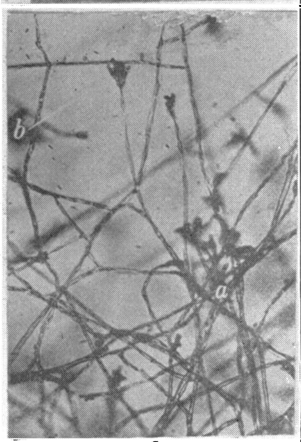

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FIG. 1. PHOTOMICROGRAPH OF A FRAGMENT OF FISH BONE FROM THE AUTUN BASIN OF FRANCE, showing the nature of the osseous lacunae, canaliculi and vascular channels.

FIG. 2. PHOTOMICROGRAPH OF ANOTHER PORTION OF THE SAME BONE showing in the enlarged canaliculi and lacunae the ravages of micrococci which have invaded the channels and have begun the destruction of the bone.

FIG. 3. PHOTOMICROGRAPH OF ANOTHER PORTION OF THE SAME BONE showing a further stage of destruction. The form of the lacunae and canaliculi are barely perceptible, since they are packed full of colonies of micrococci.

FIG. 4. SCATTERED BACTERIA IN FOSSILIZED PLANT CELLS, one of them at *a* showing faint indications of a mucoid capsule.

enlargements among recent crinoid stems, as described and figured in the Reports of the Challenger Exploring Expedition, that these enlargements were due to the parasitic action of myzostomids. Graff supported his interpretation by describing the carbonized remains of some worm, supposedly one of the myzostomids, to which the tumor was due, preserved in a channel of one of the fossil lesions. Similar objects are common from the Carboniferous of North America and doubtless they have a very wide distribution.

During the Carboniferous also there was a widespread development of fungi and bacteria which doubtless were influential in the spread of disease. Renault has found these forms abundantly preserved in the fossilized feces of fishes, in ancient wood and in coal. He also discovered in the teeth of certain extinct fishes indications of caries, as shown by the irregular decayed spots within the substance of the teeth. Renault's work covered many geological periods later than the Coal Measures, and his large monograph is the summing up of twenty-four years of activity spent in investigating the nature of the "Microorganismes des combustibles fossiles" in peat, lignite, bituminous schists (in which he found rhizopods, bacteria and fungi), boghead coal, cannel, ancient schists and the silicification of organisms in very ancient rocks. Renault's work is of great importance. A few of his figures are given herewith (Figs. 1–6). The bacteria take the form of coccoids, bacilli, diplococcoids and micrococcoids. Often in sporangia of the early cryptogamous plants Renault found natural cultures (Fig. 5) of bacteria which have been preserved by silicification. These organisms, which have been made so well known by the studies of French scholars, may all of them have been non-pathogenic forms, but the possibility of their being the cause of the disease of succeeding forms of life is very evident, and they should be mentioned as possible sources of disease.

Permian

The great Permian period, with its widespread development of curious reptilian forms, has furnished us with the first evidences of traumatic conditions as they prevailed among the early forms of life. Fractures may have occurred earlier than the Permian, but they have not yet been seen. The oldest known fractures are found among the reptiles from the Permian of Texas. A left radius of *Dimetrodon,* a primitive reptile, pre-

Fig. 5. Silicification of a Natural Culture of Bacteria from the Permian.

Fig. 6. Mycelia and Sporangia of Fossil Fungi as seen under high magnification in a thin section of fossil wood. Favorite places for the growth of bacteria. All figures taken from Renault's monograph "Microorganismes des combustibles fossiles."

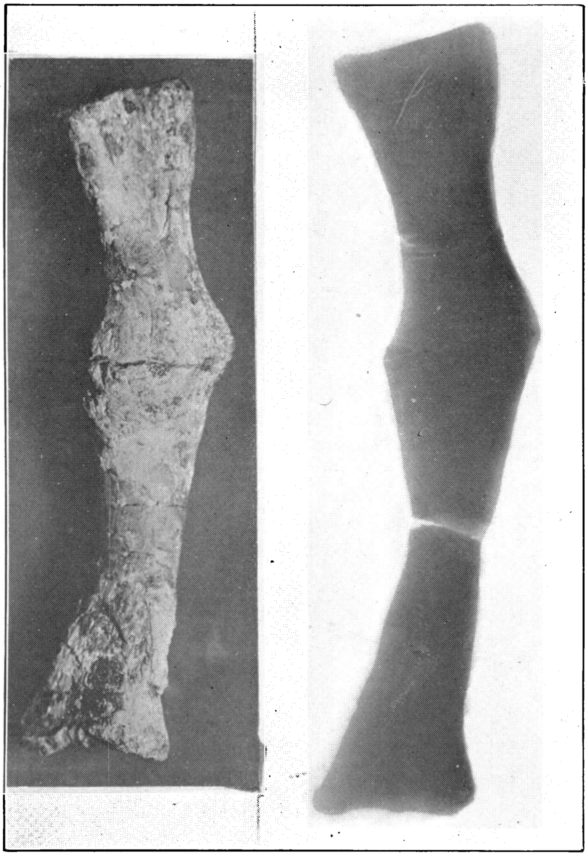

FIG. 7. LEFT RADIUS OF *Dimetrodon*, a primitive reptile from the Permian of Texas, showing, in the enlarged portion of the bone above, a simple fracture and considerable callus with some intermediary callus. Specimen the property of the Walker Museum University of Chicago. Loaned for study and description by Dr. S. W. Williston.

FIG. 8. X-RAY PICTURE OF THE BONE. The fracture lines above and below the callus are post-fossilization fractures and have no significance.

sents a well-marked case of fracture (Fig. 7) with subsequent healing, although there is still some intermediary callus. An attempt to study the nature of this fracture by means of the X-ray has not resulted in any new knowledge, but it may be interesting to present the attempt (Fig. 8). The fracture runs directly across the bone, as do all the early cases of fracture among animals with solid limb bones, and the resulting callus has produced a decided enlargement of the bone around the fracture. The fractures seen in the X-ray picture above and below the callus were produced after fossilization and have no significance.

A small fragment of a fractured rib from the same beds, in which there was quite an old callus, has been studied micro-

scopically (Fig. 9). The callus was quite evidently an old one, for the fracture was completely healed. A study of the microscopic section proves this to be true, since evidences of osteosclerosis and osteohypertrophy are clearly evident. The region

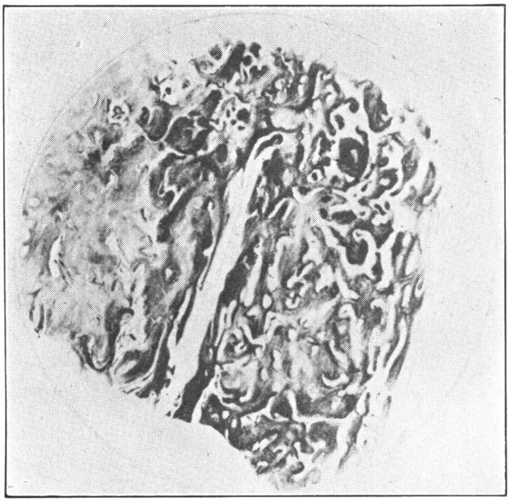

FIG. 9. MICROSCOPIC STUDY OF THE DETAILS OF A FRACTURE IN A RIB OF A REPTILE FROM THE PERMIAN OF TEXAS. The white spicule running vertically in the figure is the ingrowth of bone into a split portion of the rib. On the left of this spicule is to be seen the osteosclerotic portion of the old callus, indicated by a heavy unorganized deposit of calcium carbonate or some similar salt. On the right is seen the hypertrophied area, identified by the heavy deposition of bone with small lacunae and canaliculi. The lacunae have largely disappeared in reproduction but are clearly evident on microscopic examination of the bone.

of the figure to the left of the spicule of bone is regarded as due to osteosclerosis, which is interpreted on the basis of the presence of a heavy deposit of calcium salts and the absence of osseous trabeculae. The white band running vertically may be interpreted as a spicule of bone due to the splitting of the rib. Its bony nature is definitely established by the presence of lacunae, and its presence in this position is due to the ingrowth of new bone along a cleft produced by the splitting of the rib. The hypertrophied area to the right of the osseous band is often seen in old calluses and is interpreted on the basis of the presence of numerous trabeculae of bone. There is no evidence that the fracture was infected, necrotic sinuses being entirely wanting.

TRIASSIC

Except for occasional specimens of fossil fishes and other forms preserved in the pleurothotonos and opisthotonos (Fig. 10A), attitudes suggesting a condition of spastic distress,[3] little is known about the pathology (Fig. 10B) of the animals which

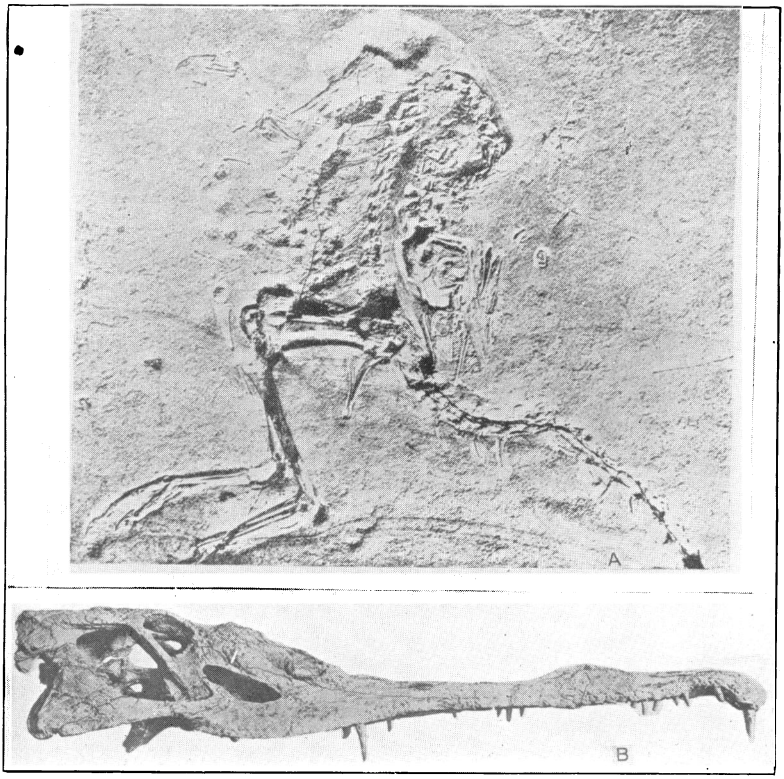

FIG. 10*A*. THE SKELETON OF *Compsognathus longipes*, a small Triassic dinosaur, fossilized in the position of opisthotonos, a position which has been suggested as an evidence of cerebrospinal infection. The head is thrown far back over the pelvis and tail thrown sharply up with the feet and limbs in a spastic attitude.

FIG. 10*B*. THE SKULL OF *Mystriosuchus Plieningeri* H. von Meyer, a parasuchian, from the Triassic of Aixheim, exhibiting a broken snout (above letter *B*) with resulting callus and bone necrosis. After Huene.

lived during the Triassic. There doubtless is much to learn in the future, since many vertebrate species are known from this period.

JURASSIC

The Jurassic of England furnishes us the first evidences of necrosis and a suggestion of metastasis as seen in the pathological nature of the bones of *Metriorhynchus moreli* Desl., a crocodile described by Erwin Auer[4] from the Oxford Clay.

The skeleton of this interesting animal was only partially preserved. There are evidences of pathology in the palate, on the two femora, on a sacral vertebra and on the pelvis. Auer says:

[3] " Studies in Paleopathology. III., Opisthotonos and allied Phenomena among fossil Vertebrates," *American Naturalist*, Vol. LI., No. 617–618, 1918.

[4] *Paleontographica*, Bd. 55, pp. 277, 279–280, figs. 13–14.

On the middle of the inferior side of the palatine is a section that is unusually differentiated by cavities, and consists of fossulae, a condition that is not otherwise encountered in crocodiles, and that doubtless is connected with the pathogenic deformities the bones exhibit.

The right femur is normally formed, but it displays below the caput femoris a peculiar corrosion, and the condylus internus is reduced at the distal end.

The left femur (Fig. 11*a*) departs in form quite considerably from the normal type. The head of the bone has undergone a significant contraction, and the formerly globular articular surface is deformed. Under

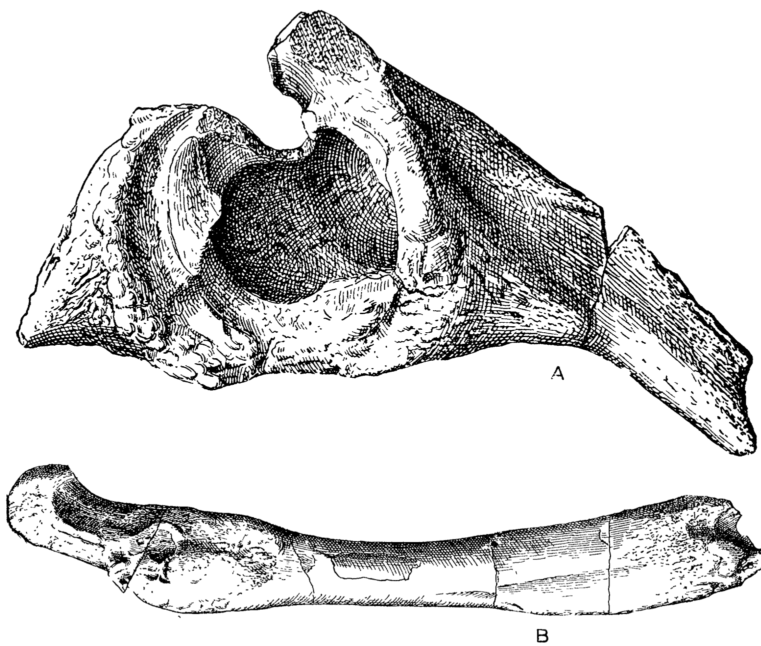

FIG. 11*A*. SACRAL VERTEBRA OF *Metriorhynchus moreli* Desl. from the Oxford Clay of England, showing carious roughening and necrosis. After Auer.

FIG. 11*B*. LEFT FEMUR OF THE SAME, showing pathological roughening at the upper and lower extremities, especially around the trochanetric region. After Auer.

the head of the bone the femur exhibits an abnormally small diameter, and on the external side of the bone a ridge is raised.

The sacral vertebra (Fig. 11*b*) also exhibits significant deformities of a pathogenic nature; the body of the vertebra is noticeably thickened, irregularly jagged on the outer side and set with numerous rather deep holes. The body of the vertebra is completely hollowed out from the end surface.

The description indicates the presence of a tuberculous or similar necrosis of the bones and is the most complete example of a seriously diseased vertebrate which has been seen in the fossil condition.

COMANCHIAN

The gigantic dinosaurs of the Comanchian have long been known to have suffered from disease and injury and the writer

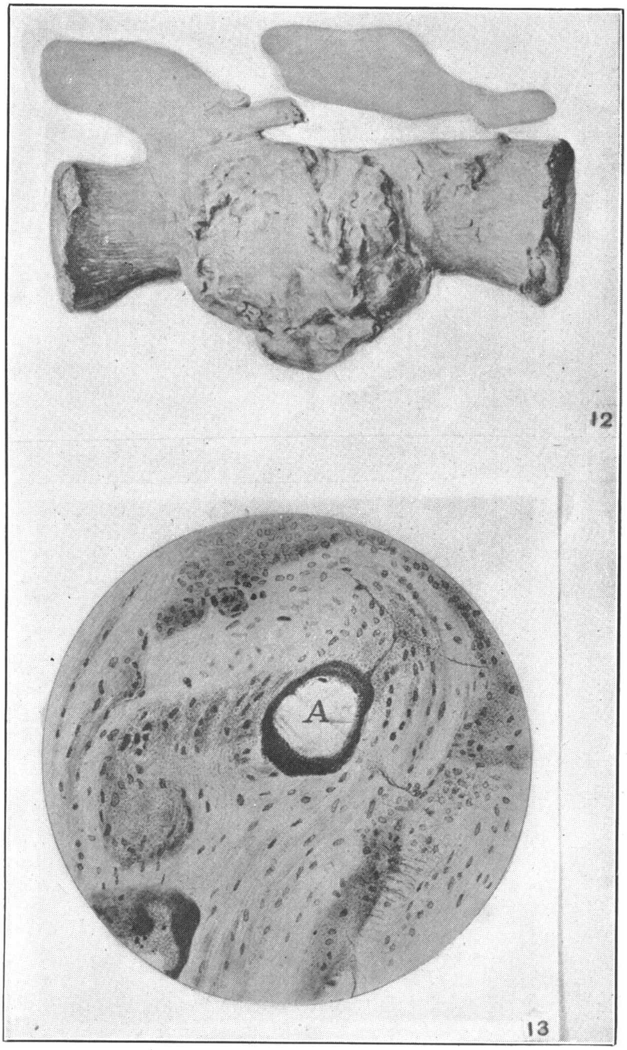

FIG. 12. DEFORMED JOINT BETWEEN TWO CAUDAL VERTEBRAE OF A DINOSAUR (*Apatosaurus*) caused by the growth of a tumor-mass, which on account of its extreme vascularity represents possibly an haemangioma, or some similar pathological growth.

FIG. 13. MICROSCOPIC SECTION OF A PORTION OF THE PERIPHERY OF ABOVE TUMOR, showing arrangement of lacunae, vascular spaces (*a*) and lamellae of bone. How much this differs in arrangement of elements from normal bone remains to be determined.

has described these sufficiently in other places[5] to make their characters well known. The most interesting lesion seen among the dinosaurs has been regarded as resembling a modern hemangioma (Figs. 12–13). Fig. 14 will show the nature of the

[5] "Pathologic Lesions among Extinct Animals: A Study of the Evidences of Disease Millions of Years Ago," *Surgical Clinics of Chicago*, Vol. 2, No. 2, pp. 319–331, Figs. 108–116, 1918.

vascular spaces and the arrangement of the osseous trabeculae as seen in a sagittal section of the tumor mass.

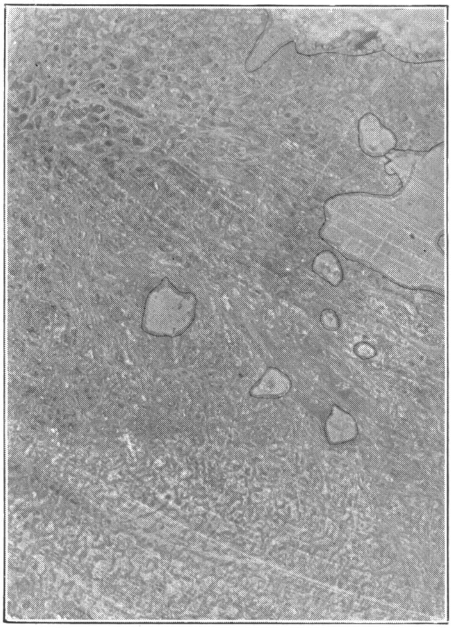

FIG. 14. PHOTOGRAPH, ENLARGED, OF THE CUT SURFACE OF THE TUMOR SHOWN IN FIG. 12, to show the arrangement of the trabeculae of bone and the large vascular spaces (areas outlined in ink). The large area at the top of the figure is apparently a portion of the intravertebral space, which has become largely obliterated by the growth of the tumor. The substance of the chevron, seen in Fig. 12 as portion of the tumor, has been incorporated, when seen in section, with the mass of pathological bone.

CRETACEOUS

The diseases of the mosasaurs may be taken as a sample of the prevalence of disease and injury among the vertebrates of the Cretaceous. These aquatic vertebrates, as well as their congeners, the plesiosaurs and dinosaurs, were afflicted with a variety of diseases and the writer has been able to study the details of the lesions on the fossils from the Cretaceous of Kansas. Twenty years age Doctor Williston called attention to the diseased nature of the arm bones of one of the Cretaceous mosasaurs. Recently I have been able to study these bones (Fig. 15). Their pathological nature and the exostoses of a hyperplastic nature are at once evident (Fig. 15). A tentative diagnosis of osteoperiostitis has been given as the cause of the lesions. Microscopic study of the lesions (Figs. 16 and 17) reveals the bony lamellae laid down in a concentric manner, as if to form Haversian systems. The lacunae are relatively large

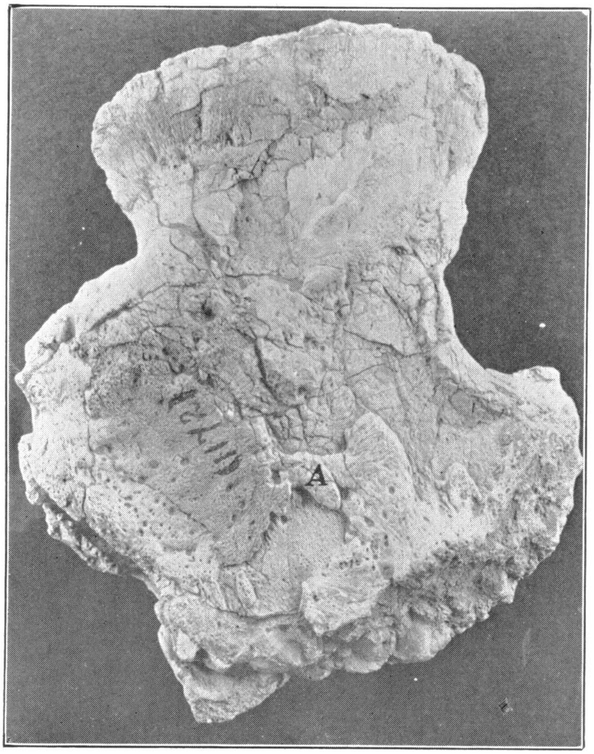

FIG. 15. HUMERUS OF A MOSASAUR, *Platecarpus coryphaeus*, from the Niobrara of Kansas showing the details of pathological lesions resembling those seen in modern osteoperiostitis. The microscopic sections (Figs. 16–17) were taken from the lesion at *A*. The disturbance also involved the articular surfaces indicating the presence of an arthritic infection.

and are provided with short canaliculi, and there are areas where osteoid tissue (Fig. 16) is present, comparable in every way with osteoid tissue, seen in modern cases of osteomyelitis. For the first time in the history of paleohistology perforating fibers of Sharpey (Fig. 17) are seen running through the sections.

A dorsal vertebra of *Platecarpus,* a well-known mosasaur from the Cretaceous of Kansas, presents an extremely interesting example of an osteoma (Fig. 18), the only one thus far known in a fossil condition. The specimen has not yet been studied microscopically, but a gross examination of a sawn section (Fig. 19) through the osteoma and vertebra shows in a very interesting manner how the tumor mass grew out of the vertebra. An X-ray examination of the bone reveals nothing of importance.

A radius of another mosasaur shows on the proximal surface an extensive necrosis. Sections of the bone show hyper-

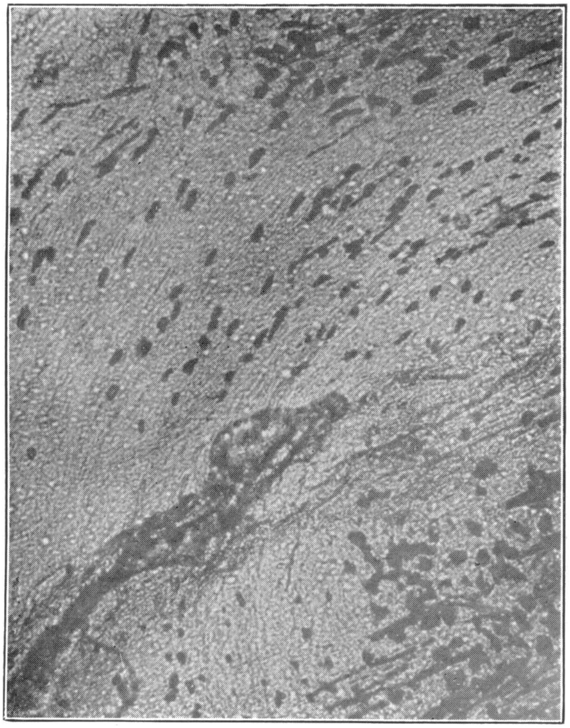

FIG. 16. PHOTOMICROGRAPH OF THE PORTION OF THE LESION (*A*, Fig. 15), showing osteoid tissue. The black lacunae are seen to be without canaliculi and their arrangement in concentric lamellae suggests the presence of an Haversian system. The dark area running obliquely out of the lower left hand corner is a post fossilization fracture filled with calcite. This area of osteoid tissue in the humerus of a mosasaur, 15,000,000 years old, is identical in anatomical structure with osteoid tissue from the human humerus in a case of osteomyelitis.

trophy of the peripheral substance. The nature of the organism producing the necrosis is not determined, but the fossil presents an exact duplicate of modern instances of extensive arthritic necrotic sinuses, which result in hypertrophy and the production of numerous osteophytes.

Dollo has described dental caries in a mosasaur jaw, with a hyperplasia of the bone with accompanying necrosis, as if the creature had suffered from a mouth infection similar to modern alveolar pyorrhea. The results are identical in modern and ancient bones.

The prevalence of disease reached a climax in the mosasaurs, dinosaurs, plesiosaurs and turtles of the Cretaceous, and with the opening of the Tertiary the incidence of disease went sharply down, to rise again with the rise of mammalian life and reach a very high point during the Pleistocene.

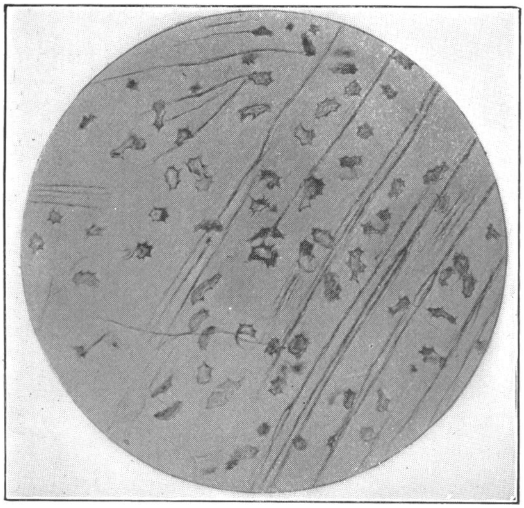

FIG. 17. MICROSCOPIC STUDY OF ANOTHER AREA OF THE SAME SECTION AS THAT SHOWN IN FIG. 16, showing the presence of perforating fibers of Sharpey, the long black fibers running obliquely through the figure, and small lacunae with short canaliculi, without any definite arrangement into systems.

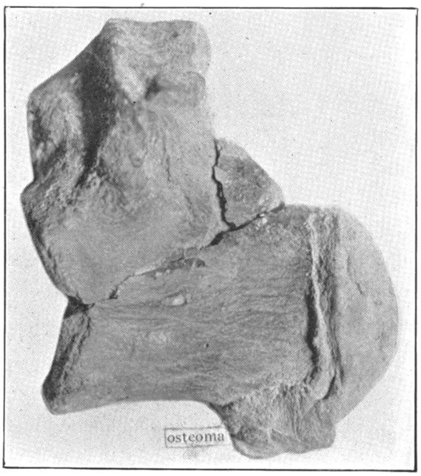

FIG. 18. A DORSAL VERTEBRA OF A MOSASAUR, *Platecarpus*, from the Niobrara of Kansas, showing on the posterior (right hand of figure) end of the vertebra an osteoma, the only known fossil representative of this type of tumor.

EOCENE

The extinction of the large groups of reptiles at the close of the Cretaceous doubtless brought about the disappearance also of many forms of disease which attacked these animals. Some forms of disease, as seen in the lesions left on the fossil

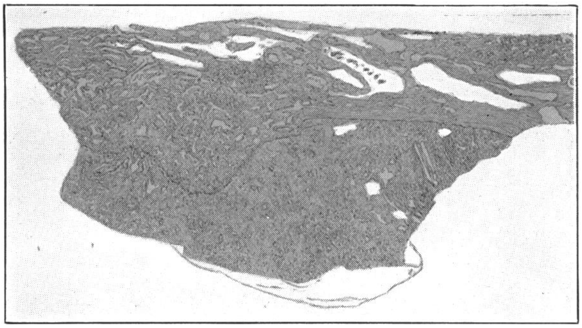

FIG. 19. A DRAWING OF A SAWN SECTION OF THE VERTEBRA, at the region of the occurrence of the osteoma, showing how the pathological structure grew out of the body of the vertebra.

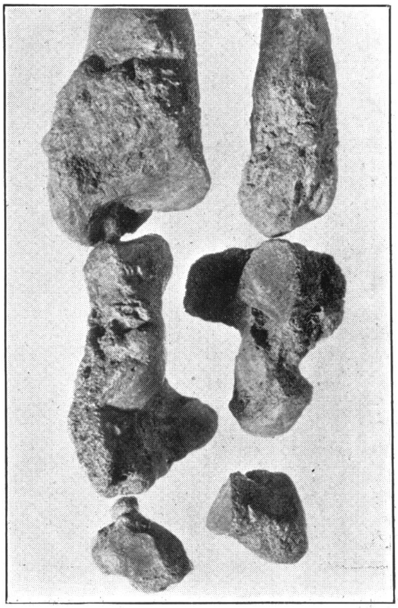

FIG. 20. TIBIA AND FIBULA WITH TARSAL BONES OF *Limnocyon potens*, a carnivore from the Washakie Eocene, showing in the carious roughening and hyperostoses evidences of disease resembling the results of osteomalacia of today. Published through courtesy of Dr. W. D. Matthew.

bones, were persistent as may be seen in cases of caries and alveolar osteitis with the associated forms of necrosis. It is to be expected that the paleontological evidences of disease would be rather scanty during the Eocene and in fact not a great deal is known. One interesting indication of a pathological condition may be seen in the tibia, fibula and associated tarsal bones of *Limnocyon potens*, a creodont carnivore from the

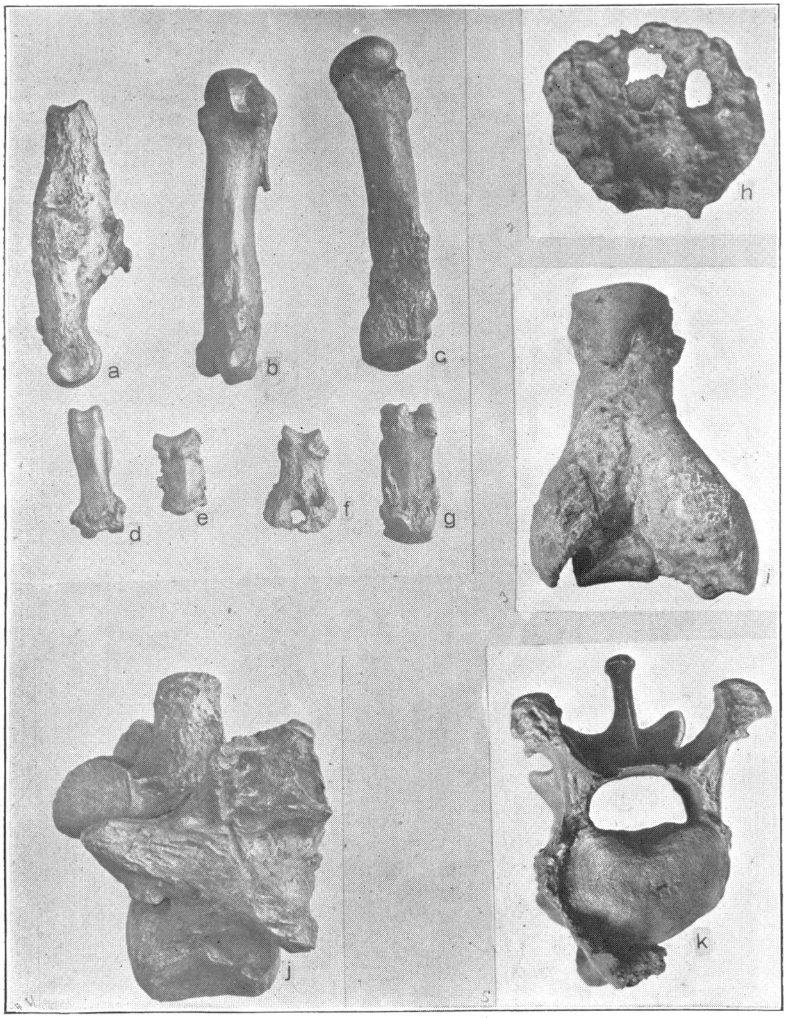

FIG. 21. *a,* metatarsal of a giant wolf, *Canis dirus,* from the Pleistocene, Rancho la Brea beds, of southern California showing a fracture of the middle of the bone with repair and the ensuing callus and exostoses. *b,* metatarsal of a saber-toothed cat, *Smilodon,* from the same deposits, showing on the upper right-hand surface a sharp exostosis, doubtless due to the infection of a tendon sheath, or some similar irritation. *c,* another metatarsal of a saber toothed cat from the same beds, showing on the lower end of the bone considerable carious roughening and hyperostosis. *d, e, g,* phalanges of a giant wolf showing slight exostoses due to some infection. *f,* phalange of a wolf. In the lower end the erosions of chronic osteomyelitis (?) or some similar long standing necrosis, produced by infection. An end view of this phalange, enlarged, is shown in *h. h,* end view of phalange (enlarged) shown in *f,* giving a clear idea of the necrosis produced by the infection. *i,* a pathologic camel phalanx from the Rock Creek beds (Pliocene or early Pleistocene) of Texas. This specimen has been discussed by Troxel (*Amer. Journ. Sci.,* XXXIX., p. 626, 1915) where he says: "Possibly the disease which caused the death of the individual also contributed to the destruction of the species." A supposition which is not supported by the evidence, since the pathological condition as seen in this single phalanx would have caused merely a stiffness and consequent lameness of the foot. Photo published by courtesy of Dr. R. S. Lull. *j,* vertebra of a saber toothed tiger from the Rancho la Brea beds of southern California, showing necrosis in the process seen on

Washakie Eocene. These bones (Fig. 20) show considerable exostoses and hypertrophy indicating an infection of some duration. The appearance of the bones suggests modern conditions of nutritional disturbances resulting in the softening and lightening of the bones as in osteomalacia.

OLIGOCENE

The mammals of the Oligocene suffered from disease and injury, though not so greatly as their successors, nor were any of the diseases prevalent at that time of sufficient importance to produce extinction. It must be remembered, however, that paleontological evidences of the antiquity of disease deal with hard parts exclusively, the soft parts known not being pathologic. The Oligocene dog, *Daphænus felinus,* so carefully and beautifully described and figured by Hatcher[6] presents on the inferior portion of both radii a symmetrical tumor-like mass, the only example of duplicate exostoses in fossil animals. The nature of the exostosis is problematical and I have not been able to find a parallel for this condition among the lesions on human bones. An excellent example of fracture with resulting callus formation and a splendid pseudarthrosis is known in a rib of the right side of *Titanotherium robustum* a perissodactyl from the White River beds of South Dakota, described by Osborn.[7] A careful account of this interesting fracture has been given by the writer,[8] accompanied by a detailed illustration of the callus.

MIOCENE

As an example of the nature of disease during the Miocene may be mentioned the nature of the lower jaw of the type skeleton of *Merychippus campestris,* a three-toed horse from the Loup Fork beds of South Dakota. One ramus of the jaw has a prominent swelling indicating the presence of a long-standing infection possibly of actinomycosis in its early stages, before the eruption of the bone took place. Alveolar osteitis with the

the upper right hand spine. *k*, end view of vertebra of saber tooth from the same beds, showing on the ventral surface of the body of the vertebra pathologic lesions of *spondylitis deformans*. Doubtless a series of vertebrae were ankylosed by the lesion, since the part shown is broken square across. Lesions of spondylitis deformans are fairly common in the mammalian remains of the Pleistocene.

[6] "Oligocene Canidæ," *Mem. Carnegie Museum,* Vol. 1, no. 2, p. 85, pl. XIX., figs. 9 and 11.

[7] *Bull. Amer. Mus. Natl. Hist.*, Vol. VII., p. 347, 1895.

[8] *Annals of Medical History,* Vol. I, No. 4, 1918.

formation of some osteophytes, resembling the results of pyorrhea are also seen, and one molar tooth is afflicted with caries, a common occurrence among fossil animals.

Pliocene, Pleistocene and Recent

The pathological conditions found among the mammals of the Pliocene, Pleistocene and Recent geological periods were the first known and have been extensively described and studied by a number of writers from Esper (1774) to Virchow (1895). There are about twenty contributions dealing with the diseased nature of bones from these periods. A review of our knowledge, especially of the pathology of fossil man, has been given elsewhere[9] and little need be said here concerning the pathological evidences from these periods. A few examples of diseased and injured bones from the Pleistocene, Rancho la Brea beds of southern California shown in Fig. 21, a–k, will give an idea of the prevalence of disease in the bones from these periods.

Summary

The above brief summary of paleontological evidences shows that in each geological period there are a few evidences of pathological processes known, although there has been no organized search made for diseased remains. In fact paleontologists as a rule have paid very little attention to evidences of pathology in fossil remains, though the subject is one which yields much that is interesting. The subject increases our vision as to the possibilities of medical history and extends our knowledge of the occurrence of disease back into geological time for many millions of years. No new ideas of pathology have been seen in the study of these ancient lesions—nor were any expected. Since the organization of animal and plant forms of ancient times differ in minute details only from those of recent times there is no reason why we should expect any new ideas. Doubtless many of the lesions described and figured above will on closer examination prove to be lesions of extinct diseases. We know from medieval history that diseases do become extinct and doubtless many of the diseases from which ancient animals suffered are now extinct. Their results, however, as seen in the fossilized bones, closely parallel the pathological anatomy of recent times.

[9] "Studies in Paleopathology. II., Pathological Evidences of Disease among Ancient Races of Man and Extinct Animals," *Surgery, Gynecology and Obstetrics*, 1918, figs. 1–45.

The question of extinction is still an open problem. A study of the paleontological evidences of disease, as seen in the bone lesions, does not help us much yet in an appreciation of what part disease may have played in extinction. The part may have been great, but this is a hypothetical assumption, based purely on analogy.

The subject of paleopathology and the significance of its study were first commented upon and developed by Sir Marc Armand Ruffer, while studying the lesions seen in Egyptian mummies. A study of fossil lesions is merely an extension of the work began by him but it broadens perceptibly the scope and value of paleopathology.